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Investment Without Regulatory Commitment: The Case of Elastic Demand

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ABSTRACT

This paper analyzes a regulation game with no commitment. I expand Besanko and Spulber's [2] framework to the case of elastic demands using a generalized Nash solution. It is found that the most important property of the equilibrium with inelastic demand is not carried over to the elastic demand case, ie., incomplete information worsens underinvestment, contrasting to Besanko and Spulber's result.

I. INTRODUCTION

Besanko and Spulber [2] analyze a regulatory environment with the regulated firm possessing private information about its cost. The structure of their model is as follows: the firm observes a realization of a cost parameter (θ) and then chooses a level of investment (k); the regulator does not observe θ but observes k, which allows him to infer θ and set the price accordingly, given that he is unable to respect any previous agreement with the firm.[2] *The demand function and the level of investment are observed by both parties without incurring any cost.*

Limiting the study to the case of a perfectly inelastic demand function, they find that the regulator is able to fully separate the different types of firms. The regulator is seen as offering a price schedule to the firm satisfying the condition that the information revealed by the firm when choosing an investment level does not induce the regulator to change its initial offer. They conclude that asymmetric information alleviates underinvestment, and overinvestment may result only for the less efficient firms, as those are the ones that need to invest more to signal their low state of technology.

In this paper I consider a similar problem but letting the demand function be elastic (with a constant elasticity greater than one). The equilibrium is also separating. Incomplete information, in contrast to the above mentioned study, worsens underinvestment for the least efficient firms. This result is due to the fact that for $\epsilon > 1$ investment is a decreasing function of the technology parameter θ, for which the inefficient firms have to invest less than in the complete information case so that the incentive compatibility constraint of the more efficient firms is satisfied.

II. THE MODEL

Let the demand function be given by

$$x = D(p) = p^{-\epsilon}, \tag{1}$$

where x represents quantity, p is the price and ϵ is the demand elasticity. An exogenously given firm is scheduled to provide the whole market. Following Besanko and Spulber, the regulated firm has a cost function

$$C(x,k,\theta) = x^2\theta/2k + rk, \tag{2}$$

[2] *As it is the case in screening models with commitment, in which the timing is basically reversed. See Baron and Myerson [1].*

where k is the level of investment, r is the rental cost of capital and θ is the efficiency parameter of the firm ($\theta \in [\theta_0, \theta_1]$). The term $x^2\theta/2k$ corresponds to operating costs, which are decreasing on the level of investment. Both the firm and the regulator know $D(p)$, while r and k are public knowledge. The state of nature θ is observed only by the firm. Consumer surplus is given by $S(p) = \int_p^\infty D(z)dz$. The regulator chooses a price p and a transfer T in order to maximize the Generalized Nash welfare function:

$$W(p,T) = [S(p)-T]^\alpha [T + pD(p) - (D(p))^2\theta/2k - sk]^{2-\alpha}. \tag{3}$$

The first bracket represents the consumer surplus net of transfers; the second is the firm's profit,[3] and $0 < \alpha \leq 2$ is a weighting parameter (ie., $\alpha = 0$ represents profit maximization).

The timing of the model is as follows: the firm observes a realization of θ; next the regulator offers a schedule $\{p(k),T(k)\}$ and finally the firm chooses k as a function of the realization θ and the schedule offered by the regulator.

At a separating equilibrium, the regulator is able to infer θ from k. Knowing this and the fact that the regulator is unable to commit to this schedule after discovering θ, the firm will choose k based on θ and the price and transfer that the regulator will set after calculating θ from k.

III. INVESTMENT UNDER COMPLETE INFORMATION

When regulatory commitment is feasible and θ is commonly known, the regulator will set p and T in such a way that price equals marginal cost and the level of capital is the level that minimizes the cost of producing x. This solution can be implemented following Loeb and Magat [6], by giving all the (gross) consumer surplus to the firm and redistributing part of it to the consumers through a lump-sum tax on the firm. In this case $p = x\theta/k$ and $k = (x^2\theta/2r)^{1/2}$. Using these two equations together with equation (1) results in

$$\dot{p} = (2\theta r)^{1/2} \tag{4}$$

$$\dot{k} = (2r)^{-(\epsilon+1)/2}\theta^{-(\epsilon-1)/2}. \tag{5}$$

In the absence of regulatory commitment, the firm maximizes its profits subject to the price and transfer arising from the maximization of (3) with respect to p and T. Using the first order conditions in the maximization of equation (3) and noting that $S'(p) = -D(p)$, we can obtain that $p = x\theta/k$ and $T = S(p)((2\alpha)/2) +$

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[3] *Observe that the regulator considers as rental cost of capital only the scrap value of capital, s, where $s \leq r$, with $s < r$ corresponding to the case where some investment costs are sunk.*

$[x^2\theta/2k+sk-px]$, which, after using equation (1) and noting that $S(p) = p^{-(\epsilon-1)}/(\epsilon-1)$ can be solved together resulting in

$$\tilde{p} = (\theta/k)^{1/(1+\epsilon)}, \text{ and} \tag{6}$$

$$\tilde{T} = [(4-\alpha-\alpha\epsilon)/(4\epsilon-4)](\theta/k)^{(1-\epsilon)/(1+\epsilon)} + \alpha sk/2. \tag{7}$$

The firm's problem is then to max $\Pi = T + pD(p) - (D(p))^2\theta/2k - rk$ with respect to k, subject to equations (1), (6) and (7). After introducing these equations into Π and solving for k we obtain

$$\tilde{k} = [2(2r-\alpha s)/(2-\alpha)]^{-(1+\epsilon)/2}\theta^{(1-\epsilon)/2}. \tag{8}$$

Comparing $\tilde{k}$ in (8) and $\hat{k}$ in (5), we obtain $\tilde{k} \leq \hat{k}$, with strict inequality for $s < r$ (underinvestment results from lack of commitment) . Also, from (8) we obtain the expected result $\partial\tilde{k}/\partial\alpha < 0$. (Note that $\tilde{k} = \hat{k}$ if $\alpha = 0$, and $\tilde{k} = 0$ if $\alpha = 2$).

IV. INVESTMENT UNDER INCOMPLETE INFORMATION[4]

Let $g(\theta)$ be the regulator's prior beliefs about θ. After observing k the regulator updates its prior beliefs about θ. Let $\delta(k)$ be the expected value of θ after observing k.[5]

Definition:

A sequential equilibrium for the regulation game consists of the strategies $k^*(\theta)$, $p^*(k)$ and $T^*(k)$, and beliefs $\delta^*(k)$ such that:

(A) The firm chooses $K^*(\theta)$ to max $\Pi(k,p^*,T^*,\delta^*) = T^* + p^*D(p^*) - (D(p^*))^2\theta/2k - rk$

(B) The regulator chooses $p^*(k)$ and $T^*(k)$ to max $W(k,p,T,\delta^*)$

$= (S(p)-T)(T + pD(p) - (D(p))^2\delta^*(k)/2k - sk)$

(C) The regulator's beliefs on the equilibrium path, $k^{*-1}(k) \neq 0$, are consistent with Bayes' rule and the firm's equilibrium strategy $k^*(\theta)$.

Note that with incomplete information a separating equilibrium has to respect the incentive compatibility constraint given by

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[4] *To simplify the algebra I consider $\alpha = 1$ in this section.*

[5] *It becomes obvious later that the prior $g(\theta)$, which plays a crucial role in screening models with commitment as [1], is totally irrelevant for the (separating) equilibrium without commitment.*

$$\Pi(\theta,k^*(\theta)) \geq \Pi(\theta,k^*(\tilde{\theta})) \text{ for all } \theta \text{ and } \tilde{\theta} \in [\theta_0,\theta_1]^6 \qquad (9)$$

In what follows I first show the difficulty one faces when trying to characterize the equilibrium, and then I identify two particularities of the equilibrium: incomplete information worsens underinvestment and the incentive compatibility constraint binds in only one direction. These two properties are illustrated in a discrete treatment of the equilibrium.

IV.1. Trying to characterize the equilibrium.

When the demand function is given by (1), the firm's problem can be written as

max $\Pi(\theta,k) = T(k) + p(k)^{1-\epsilon} - p(k)^{-2\epsilon}\theta/2k - rk$ *with respect to k. The first order condition for a maximum is*

$T(k)' + (1-\epsilon)p(k)^{-\epsilon}p(k)' + \epsilon\theta p(k)'p(k)^{-(2\epsilon+1)}/k + p(k)^{-2\epsilon}\theta/2k^2 = r$, *from which we obtain*

$$\theta = [r-T(k)'-(1-\epsilon)p(k)^{-\epsilon}p(k)']/[\epsilon p^{-(2\epsilon+1)}p(k)'/k+p(k)^{-2\epsilon}/2k^2]. \qquad (10)$$

In equilibrium, $\delta(k) = \theta$, *so we can replace (10) into (6) and (7) to obtain p(k) and T(k) under incomplete information. Replacing (10) into (6) and after a few algebraic steps,*

$$p(k)' = (r-T(k)')p(k)^{\epsilon} - p(k)/2k.$$

Also, from (6) and (7), $T(k) = [(3-\epsilon)/4(\epsilon-1)]p(k)^{\epsilon-1} + sk/2$. *Then,* $T(k)' = [(3-\epsilon)/4]p(k)^{\epsilon}p(k)' + s/2$ *can be replaced into p(k)' to obtain the differential equation in p(k) below*

$$p(k)' = 2(2r-s)p(k)^{\epsilon}(4+(3-\epsilon)p(k)^{2\epsilon})^{-1}-[2p(k)/k][4+(3-\epsilon)p(k)^{2\epsilon}]^{-1},$$

whose solution would characterize the equilibrium up to a constant of integration[7]. Obviously, the difficulty found in characterizing the equilibrium consists of the difficulty of solving this differential equation. Nevertheless, certain (important) properties of the equilibrium are identified below.[8]

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[6] *The individual rationality constraint is always satisfied by construction of the welfare function as long as the project is desirable, which is assumed to be the case.*

[7] *which can be assigned a particular value using the universal divinity criterium (it basically requires that positive probability be assigned only to those types that would benefit the most from deviation.) See Besanko and Spulber [2], Cho and Kreps [3] and footnote 14.*

[8] *It is assumed that a separating equilibrium does in fact exist. See footnote 9 below for a formalization of this assumption.*

IV.2. Firms underinvest relative to complete information.

Recall that $\partial\tilde{k}/\partial\theta < 0$, *so* $\delta'(\theta) < 0$ *is a sensible condition to impose on the beliefs of the regulator. Note also that* $p^*(\delta(k))$ *and* $T^*(\delta(k))$ *are given by the adaptation to incomplete information of (6) and (7) below,*

$$\tilde{p} = (\delta(k)/k)^{1/(1+\epsilon)}, \text{ and} \tag{11}$$

$$\tilde{T} = [(4-\alpha-\alpha\epsilon)/(4\epsilon-4)](\delta(k)/k)^{(1-\epsilon)/(1+\epsilon)} + \alpha sk/2. \tag{12}$$

Replacing (11) and (12) into the profit function of the firm,

$$\Pi(\theta,p(\delta),T(\delta),\delta(k)) = [(3-\epsilon)/(\epsilon-1)][\delta(k)/k]^{(1-\epsilon)/(1+\epsilon)} + sk/2 + (\delta(k)/k)^{(1-\epsilon)/(1+\epsilon)} - (\delta(k)/k)^{-2\epsilon/(1+\epsilon)}\theta/2k - rk.$$

Rearranging terms,

$$\Pi(\theta,p(\delta),T(\delta),\delta(k)) = [\delta(k)/k]^{(1-\epsilon)/(1+\epsilon)}\{(3\epsilon-1)/4(\epsilon-1) - \theta/2\delta(k)\} + (s-2r)k/2.$$

Differentiating with respect to k and evaluating at $\delta(k) = \theta$, *ie., at the equilibrium,*

$$\partial\Pi/\partial k = (1/4)(\theta/k)^{(1-\epsilon)/(1+\epsilon)}[\delta'(k)/\theta + 1/k] + (s-2r)/2 = 0$$

is the first order condition for a maximum.[9] *If* $\delta'(k) = 0$, *as with complete information,* $\partial\Pi/\partial k = 0$ *occurs at* $k^*(\theta) = \tilde{k}(\theta) = [2(2r-s)]^{-(1+\epsilon)/2}\theta^{(1-\epsilon)/2}$. *Nevertheless, if* $\delta'(k) < 0$, *the sensible case with incomplete information,* $\partial\Pi/\partial k < 0$ *at* $\tilde{k}(\theta)$, *which means that* $k^*(\theta) < \tilde{k}(\theta)$.[10]

IV.3. The incentive compatibility constraint only binds in one direction.

To see this consider the following question: Given a level of investment $k_g = \tilde{k}(\theta_i)$, *would a firm* θ_i *want to be taken as a* θ_j *firm, with* $i > j$, *ie., with* $\theta_i > \theta_j$?

Let $\Pi(\theta_j/\theta_i,\tilde{k}(\theta_i))$ *denote the profit of a* θ_i *firm when invests* $\tilde{k}(\theta_i)$ *and the regulator believes its type is* θ_j. *Then, using equations (1),(6) and (7) and regrouping terms,*

$$\Pi(\theta_i/\theta_i,\tilde{k}(\theta_i)) = (\theta_i/k(\theta_i))^{(1-\epsilon)/(1+\epsilon)}[(\epsilon+1)/4(\epsilon-1)] + (s/2-r)\tilde{k}(\theta_i) \text{ and}$$

$$\Pi(\theta_j/\theta_i,\tilde{k}(\theta_i)) = (\theta_j/k(\theta_i))^{(1-\epsilon)/(1+\epsilon)}[(3\epsilon-1)/4(\epsilon-1)-\theta_i/2\theta_j] + (s/2-r)\tilde{k}(\theta_i).$$

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[9] *The second order condition for a maximum is given by* $\partial^2\Pi/\partial k^2$ *(evaluated at* $\delta(k) = \theta$*)* < 0, *where*

$$\partial^2\Pi/\partial k^2 = -[\delta(k)/k]^{-2\epsilon/(1+\epsilon)}\{[(7\epsilon+1)/4(\epsilon+1)](\delta'(k)^2/k\delta(k)) + [(1-\epsilon)/(1+\epsilon)]\delta'(k)/k^2 + \delta''(k)/2k\}.$$

It is assumed that $\delta'(k)$ *and* $\delta''(k)$ *are such that this condition is satisfied. Note that if* $\delta''(k) \geq 0$, $\delta'(k) < 0$ *is sufficient to satisfy this condition, in which case a separating equilibrium does in fact exist.*

[10] *In Besanko and Spulber [2],* $\partial\Pi/\partial k = s/2 - r + \theta/k^2 - \delta(k)/2k^2 + \delta'(k)/2k$, *which evaluated at* $\delta(k) = \theta$ *and since* $\delta'(k) > 0$ *when* $\epsilon = 0$ *results in* $k(\theta)^* > \tilde{k}(\theta)$.

Furthermore, $\Pi(\theta_i/\theta_i,\tilde{k}(\theta_i)) > \Pi(\theta_j/\theta_i,\tilde{k}(\theta_i))$ *if and only if*

$(\theta_i)^{(1-\epsilon)/(1+\epsilon)}[(\epsilon+1)/4(\epsilon-1)] > (\theta_j)^{(1-\epsilon)/(1+\epsilon)}[(3\epsilon-1)/4(\epsilon-1)-\theta_i/2\theta_j]$, *which is equivalent to* $A > \theta_i/\theta_j > 1$, *where*

$$A = \{[(\epsilon+1)/4(\epsilon-1)]/[(3\epsilon-1)/4(\epsilon-1)-\theta_i/2\theta_j]\}^{1(1+\epsilon)/(\epsilon-1)}.$$

Note that $A > 1$ *for all* $\epsilon > 1$ *and that* $A = 1$ *if* $\theta_i = \theta_j$. *Then, a sufficient condition for* $A > \theta_i/\theta_j$ *is* $\partial A/\partial(\theta_i/\theta_j) > 1$. *Since* $\partial A/\partial(\theta_i/\theta_j) = 2A^{2\epsilon/(1+\epsilon)}$, *and since A is greater than one for all* $\theta_i > \theta_j$, *this condition is satisfied, meaning that a firm would not like to be taken by a more efficient one given its level of investment under complete information.*

Let us now reverse the roles of i and j so consider the incentives firms have to be confused with a less efficient one. Note that if $j > i$, $A < 1$ *for all* $\epsilon > 1$ *and* $A = 1$ *if* $\theta_i = \theta_j$. *Then,* $A > \theta_i/\theta_j$ *if* $\partial A/\partial(\theta_i/\theta_j) < 1$. *But* $\partial A/\partial(\theta_i/\theta_j) = 2A^{2\epsilon/(1+\epsilon)}$ (< 2) *is not necessarily less than one.*[11] *This means that firms want to be taken by a (closely) less efficient one.*

Up until now it was shown that if the regulator asks a firm about its type, an inefficient firm would never say it is more efficient than its true type, and that in fact it has an incentive to tell the regulator that it is (not much) less efficient than the truth. Now, consider the case in which firms signal that they are less efficient by investing less and suppose that there is a benefit attached to this different level of investment. Making use of continuity, the marginal benefit from this different level of investment is of second order, while the gains from misrepresentation by the relatively efficient firms remains intact. Therefore, the more efficient firms have much stronger incentives to imitate less efficient firms, which means that the incentive compatibility constraint given by (9) binds in only one direction, ie., for $\tilde{\theta} > \theta$.

IV.4. A discrete example.

This subsection makes use of subsection IV.3. to characterize the sequential equilibrium when θ *takes only two values,* θ_o *or* θ_1, *with* $\theta_1 > \theta_0$. *From the discussion above, only the second of the two incentive compatibility constraints below is binding,*[12]

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[11] *By continuity, for* θ_i *sufficiently close to* θ_j, $\partial A/\partial(\theta_i/\theta_j) > 1$. *See footnote 12 below.*

[12] *Note that it may happen that neither constraint binds when there is a discrete number of types, ie., if the types are too different from each other. In this case incomplete information has no effect on investment. I abstract from this case. Furthermore, as in Milgrom and Roberts [4] for the case of limit pricing, the constraint*

$$\Pi(\theta_1,k^*(\theta_1)) \geq \Pi(\theta_1,k^*(\theta_0)) \tag{9'}$$

$$\Pi(\theta_0,k^*(\theta_0)) \geq \Pi(\theta_0,k^*(\theta_1)). \tag{9''}$$

Furthermore, if the equilibrium is separating, $k^*(\theta_0) = \tilde{k}(\theta_0)$, *since the most efficient firm is never imitated by a less efficient one and therefore does not have to deviate from the complete information level of investment to signal its type.*

Finally, the beliefs that support the separating equilibrium are given by

$$\delta(k) = \theta_1 \text{ if } k = k^*(\theta_1),\ \theta_0 \text{ otherwise.}^{13,14} \tag{13}$$

Therefore, $k^*(\theta_1)$ *is given by* $\Pi(\theta_0,k^*(\theta_0)) = \Pi(\theta_0,k^*(\theta_1))$[15], *which after replacement of (11), (12) and (13) results in (14) below*

$$(\theta_0/k^*(\theta_0))^{(1-\epsilon)/(1+\epsilon)}(\epsilon+1)/4(\epsilon-1) + (s/2-r)[k^*(\theta_0)-k^*(\theta_1)] -$$

$$(\theta_1/k^*(\theta_1))^{(1-\epsilon)/(1+\epsilon)}[(3\epsilon-1)/4(\epsilon-1) - \theta_0/2\theta_1] = 0 \tag{14}$$

Summarizing, for $\theta \in \{\theta_0,\theta_1\}$, *the (universally divine) sequential equilibrium involves*

$$\tilde{p} = (\delta(k)/k)^{1/(1+\epsilon)}, \tag{11}$$

$$\tilde{T} = [(4-\alpha-\alpha\epsilon)/(4\epsilon-4)](\delta(k)/k)^{(1-\epsilon)/(1+\epsilon)} + \alpha sk/2 \tag{12}$$

$$\delta(k) = \theta_1 \text{ if } k = k^*(\theta_1),\ \theta_0 \text{ otherwise} \tag{13}$$

$k^*(\theta_0) = \tilde{k}(\theta_0) = [2(2r-s)]^{-(1+\epsilon)/2}\theta_0^{(1-\epsilon)/2}$ *and* $k^*(\theta_1)$ *implicitly given by*

$$(\theta_0/k^*(\theta_0))^{(1-\epsilon)/(1+\epsilon)}(\epsilon+1)/4(\epsilon-1) + (s/2-r)[k^*(\theta_0)-k^*(\theta_1)] -$$

$$(\theta_1/k^*(\theta_1))^{(1-\epsilon)/(1+\epsilon)}[(3\epsilon-1)/4(\epsilon-1) - \theta_0/2\theta_1] = 0. \tag{14}$$

For example, for $\theta_0 = 1$, $\theta_1 = 3/2$, $r = 1$, $s = 4/5$ *and* $\epsilon = 2$, $\tilde{k}(\theta_0) = k^*(\theta_0) = 0.2689$, $\tilde{k}(\theta_1) = 0.2196$ *and* $k^*(\theta_1) = 0.125$. *It is easy to check that this is indeed and equilibrium. (And that the incentive compatibility constraint does not bind for the firm with cost parameter* θ_1.*)*

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is always binding when there is a continuum of firms.

[13] *Beliefs* $\delta(k) = \theta_1$ *if* $k \leq k^*(\theta_1)$, $\delta(k) = \theta_0$ *otherwise would work also.*

[14] *Note that these beliefs respect the universal divinity criterium (see Cho and Kreps [3]). To see this, note that beliefs* $\delta(k) = \theta_1$ *if* $k \leq k^{**}(\theta_1)$, $\delta(k) = \theta_0$ *otherwise, where* $k^{**}(\theta_1) < k^*(\theta_1)$, *would support other separating equilibria. Nevertheless, these beliefs do not respect the universal divinity criterium for out of equilibrium beliefs, since the regulator believes* $\delta(k^*(\theta_1)) = \theta_0$, *which is not sensible since the firm with cost parameter* θ_0 *would never, regardless of what the regulator believes, choose* $k^*(\theta_1)$.

[15] *We assume the firm is truthful whenever it is indifferent.*

IV.5. An approximation to the continuous case.

Lastly, we close this section by extending the characterization of the sequential equilibrium with two types to n types. Notice that the equilibrium relationship in the previous subsection can be repeated between the firm with cost parameter θ_1 and another firm characterized by θ_2, where $\theta_2 > \theta_1$, provided that the relationship between $k^*(\theta_0)$ and $k^*(\theta_1)$ is as before[16]. *The equilibrium below makes use of this property between any two contiguous types of firms.*

Let $\theta \in \{\theta_0, \theta_1, ..., \theta_n\}$. Then, the (universally divine) sequential equilibrium involves $p^*(k)$ and $T^*(k)$ as before,

$$\delta(k) = \begin{cases} \theta_i \text{ if } k = k^*(\theta_i), \text{ for } i = 1,....,n. \\ \theta_0 \text{ otherwise.} \end{cases}$$

$k^*(\theta_0) = \bar{k}(\theta_0) = [2(2r-s)]^{-(1+\epsilon)/2}\theta_0^{(1-\epsilon)/2}$ *and $k^*(\theta_1)$ implicitly given by*

$$(\theta_{i-1}/k^*(\theta_{i-1}))^{(1-\epsilon)/(1+\epsilon)}(\epsilon+1)/4(\epsilon-1) + (s/2 - r)[k^*(\theta_{i-1}) - k^*(\theta_i)] -$$
$$(\theta_i/k^*(\theta_i))^{(1-\epsilon)/(1+\epsilon)}[(3\epsilon-1)/4(\epsilon-1) - \theta_{i-1}/2\theta_i] = 0,$$

for $i = 1,...,n$.

Here again, as in the example in subsection IV.4 illustrated, underinvestment results for all but one (θ_0, the most efficient) firms, provided that successive types of firms are not too far apart[17].

V. CONCLUSION

This paper considers a one period regulatory game in which a firm possessing private information about its cost is regulated by a regulator who cannot commit not to use the information revealed after observing the firm's investment decision.

Besanko and Spulber characterize the separating equilibrium for an inelastic demand. In their framework, the extent of underinvestment resulting from lack of commitment is alleviated when there is asymmetric information, and overinvestment may result for the less efficient firms.

In this paper I consider the case of an elastic demand. The equilibrium is also separating but incomplete information accentuates the underinvestment resulting from lack of commitment. This difference is due

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[16] *This is possible because the incentive compatibility constraint binds in only one direction.*

[17] *See footnote 12.*

to the fact that the level of investment is a decreasing function of θ when $\epsilon > 1$, so that the less efficient firms would be imitated by the more efficient ones unless they reduce investment beyond the full information level.[18]

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[18] *In Besanko and Spulber's model, ie., with $\epsilon = 0$, investment is a positive function of the cost parameter θ, so that the high cost firms signal their type by investing more than the full information level, therefore alleviating the underinvestment caused by lack of commitment.*

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